SIEMENS

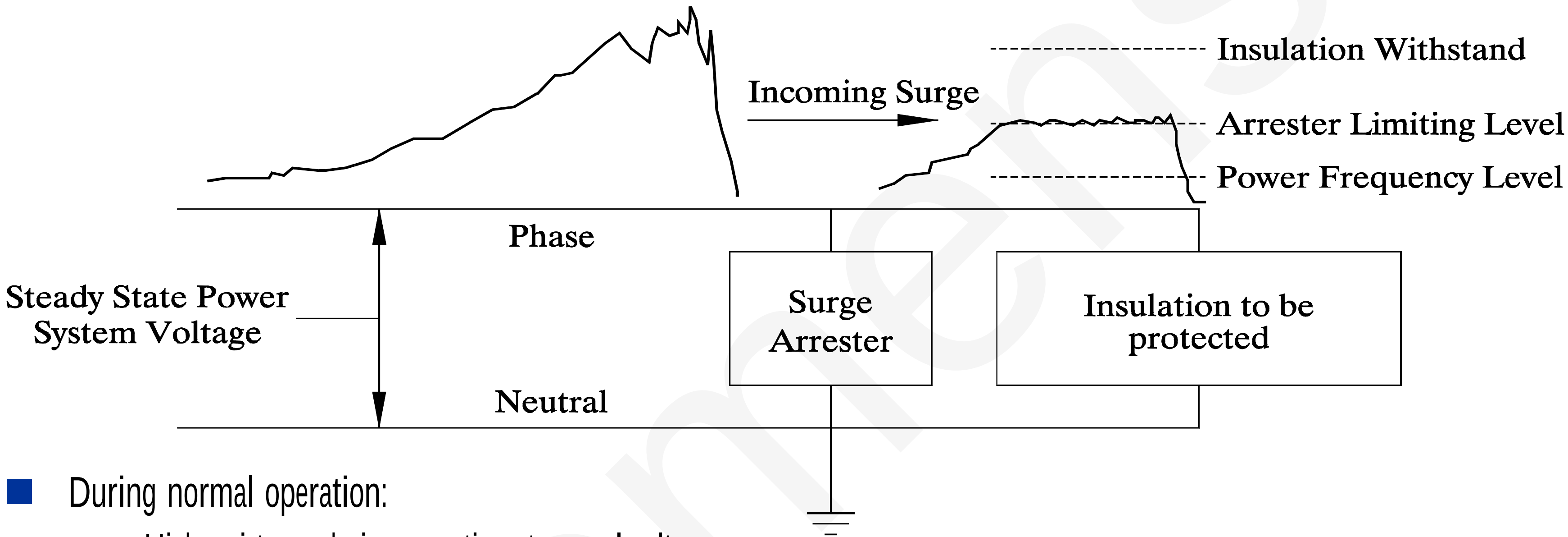
Tab 8 Surge Arresters

Distribution System Engineering Course – Unit 10

- The main protective devices against system transient overvoltages.
- The key component in insulation coordination
- Extensively used to protect non self-restoring insulation of power transformers

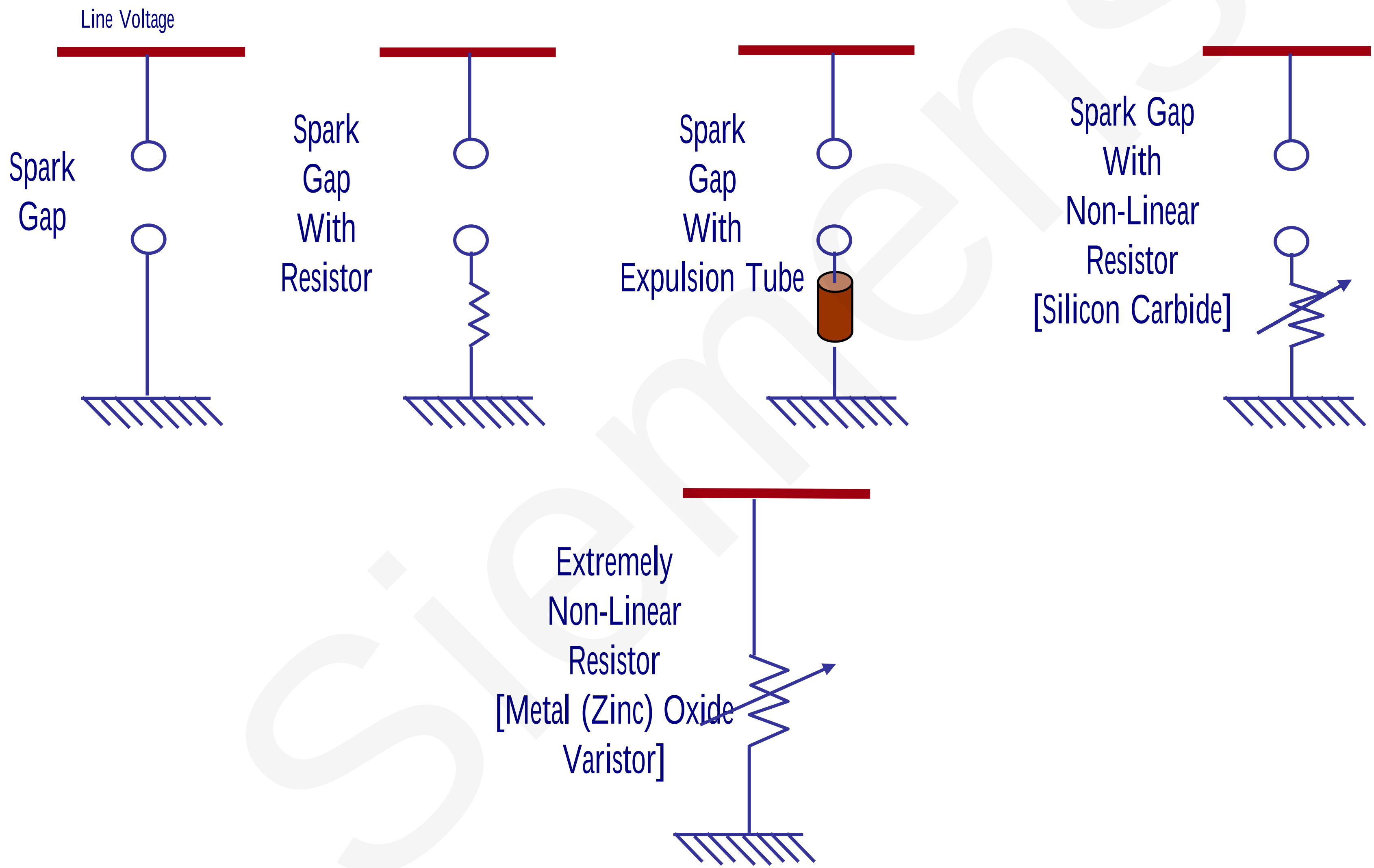
Functions of a Surge Arrester

SIEMENS



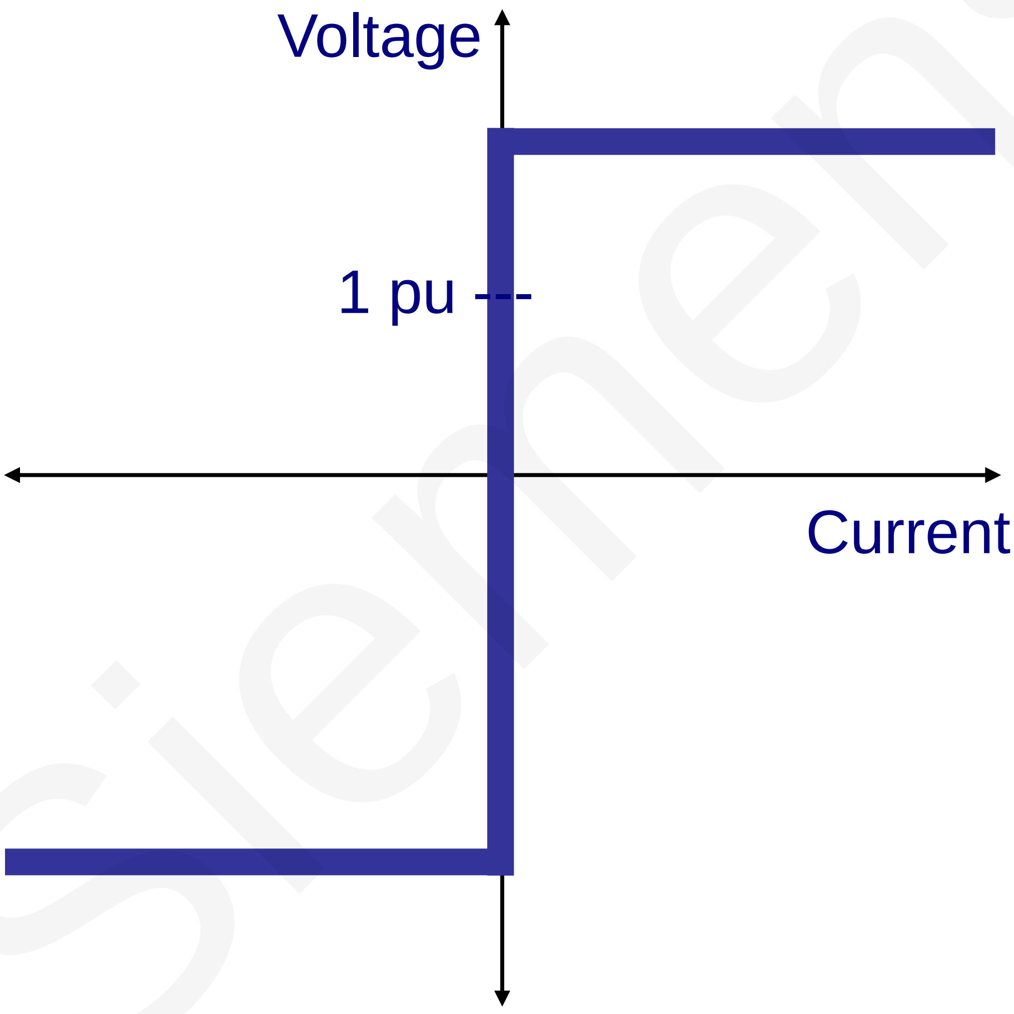
- During normal operation:
  - High resistance during operation at normal voltages
  - Only a small flow of current
  - No adverse effect on the power system
- Limit overvoltages to prevent insulation failures
  - Low resistance during overvoltages
  - High discharge current
  - Sufficient energy absorption capability for stable operation
  - Withstand surges without incurring any damage and without causing a fault

Surge Arrester Evolution



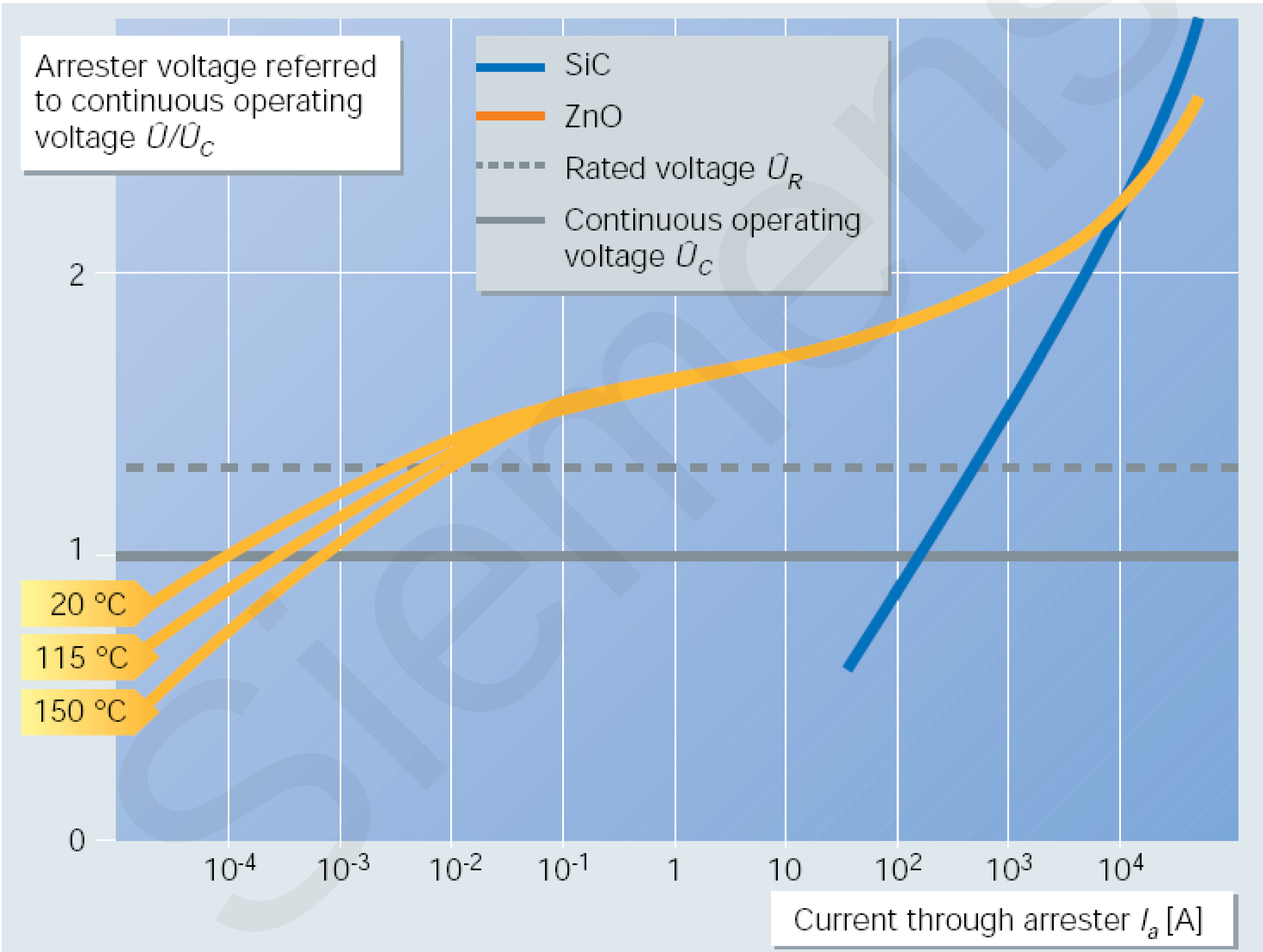
Ideal Arrester

SIEMENS



Metal Oxide vs. Silicon Carbide
V-I Characteristic

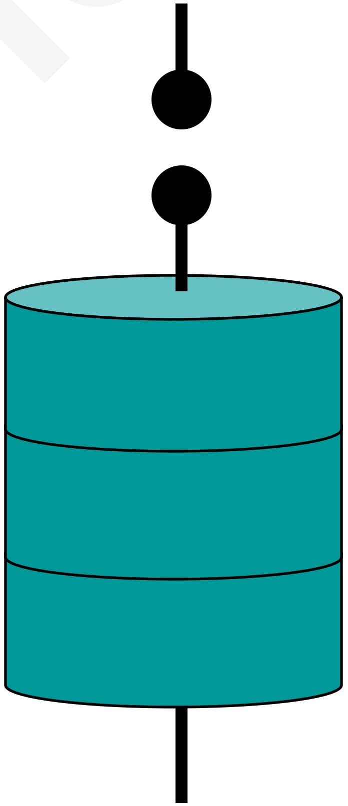
SIEMENS



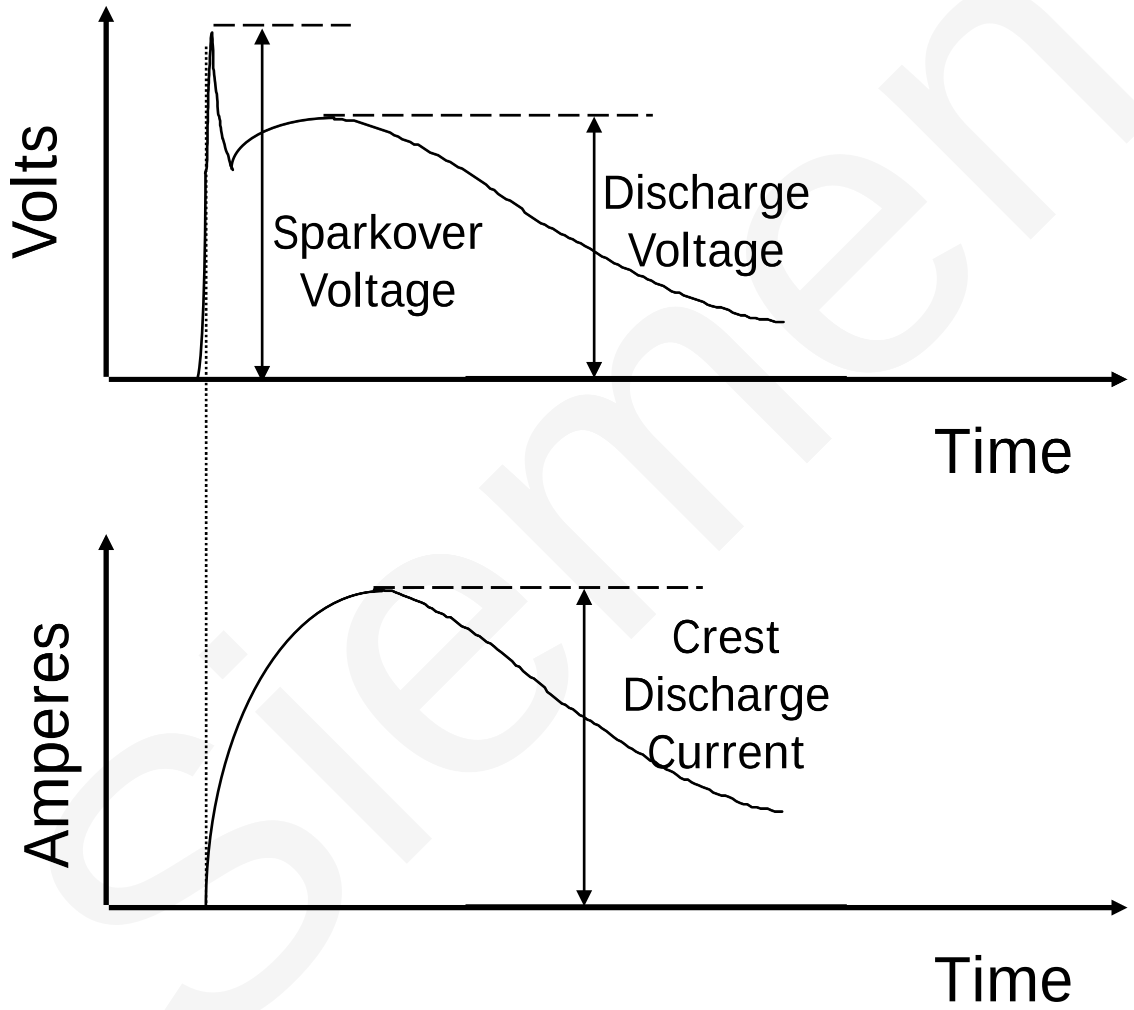
Silicon Carbide (SiC) Arrester

SIEMENS

- The spark gap assembly contains multiple series gaps and voltage grading components
- Spark gap withstands the normal power frequency voltage
- Typical spark over is 1.8-1.9 pu
- After spark over, most of the voltage drop is across the SiC blocks
- Current continues to flow until a power frequency current zero

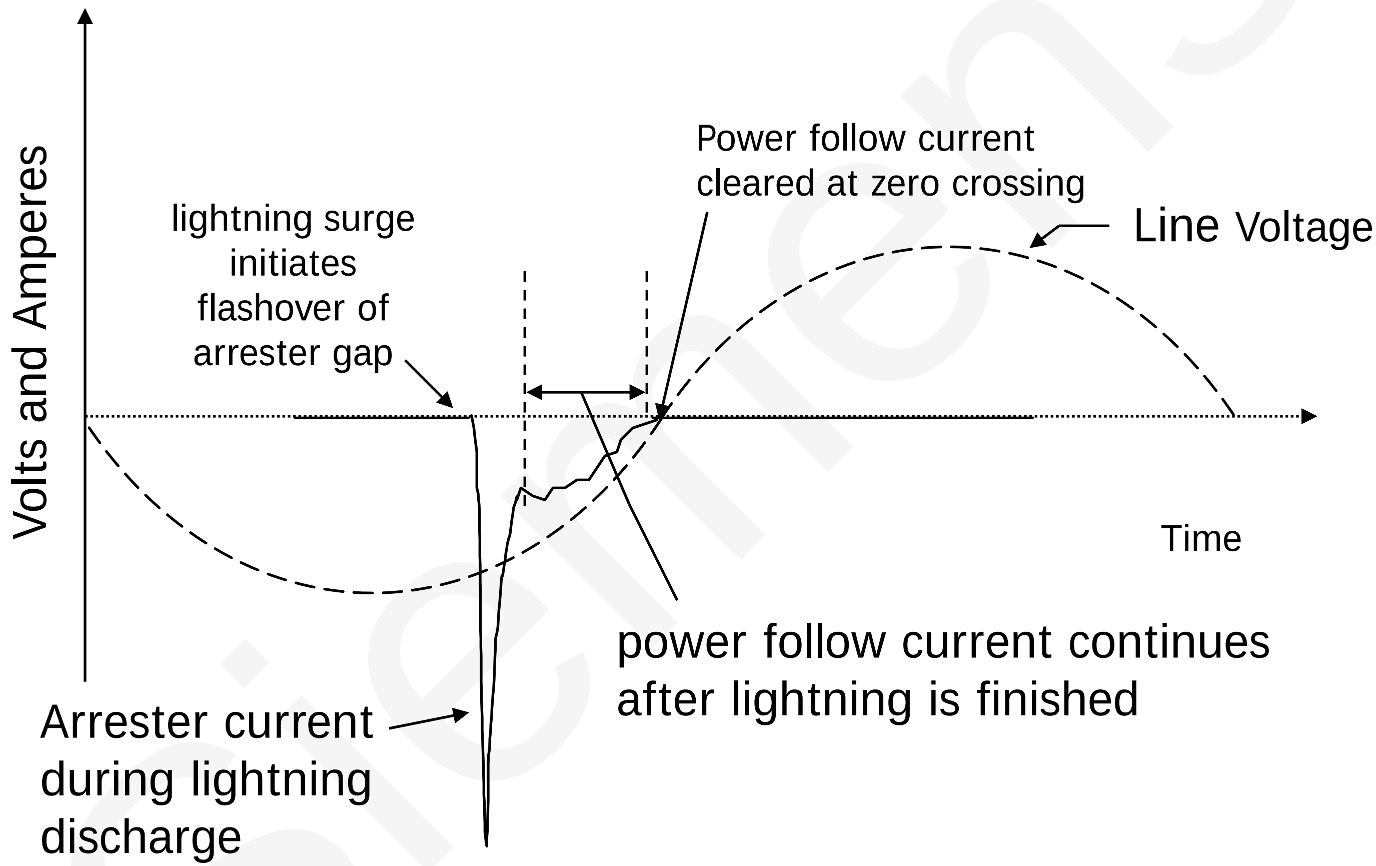


Silicon Carbide Arrester



Current in an SiC Arrester

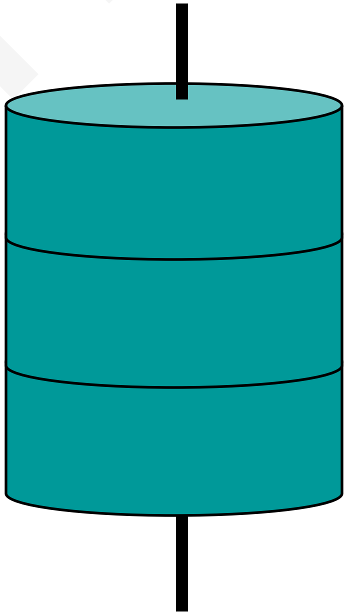
SIEMENS



Metal Oxide Varistor (MOV)

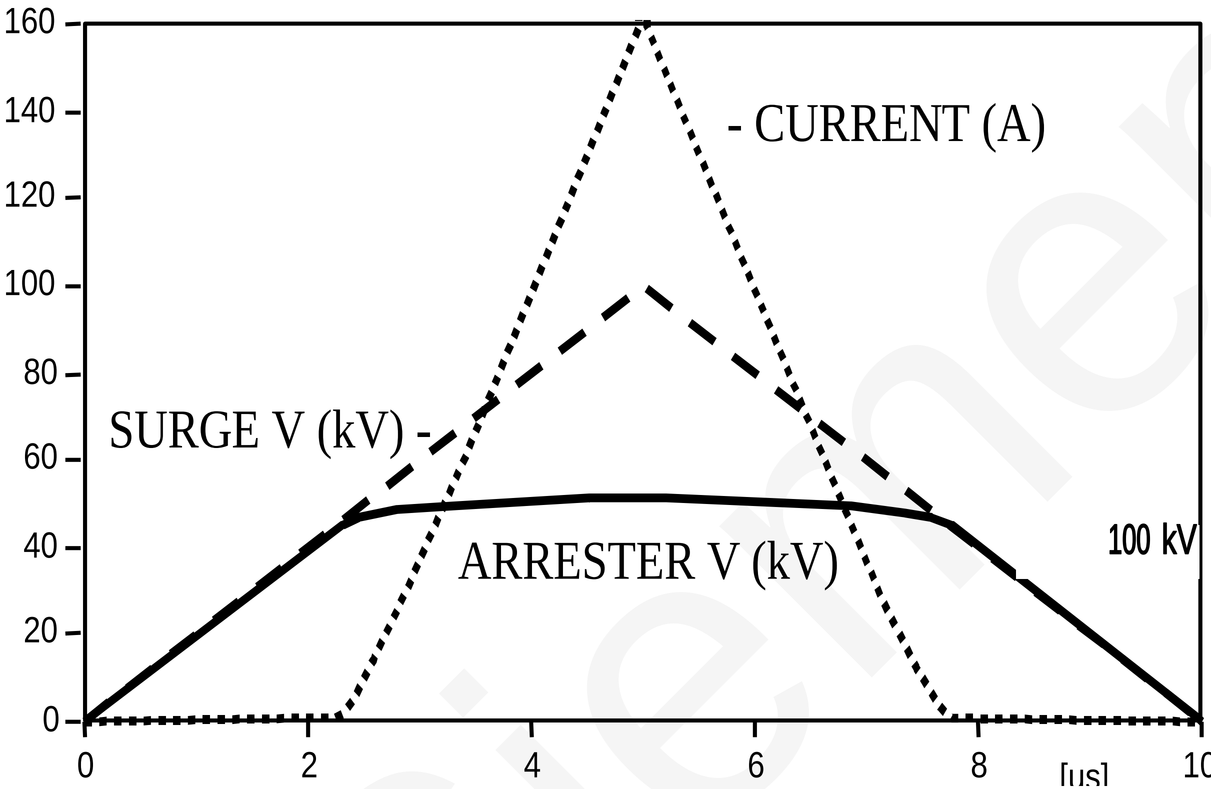
SIEMENS

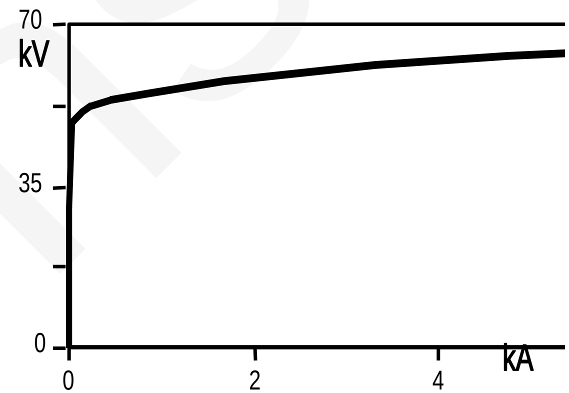
- No spark gaps for most HV & EHV MOV arresters
- MOV blocks must withstand the normal power frequency voltage with little current flow
- Typical range for onset of significant current flow is 1.7-1.8 pu
- Current flow diminishes as soon as voltage surge subsides (does not ‘wait’ until a power frequency current zero)

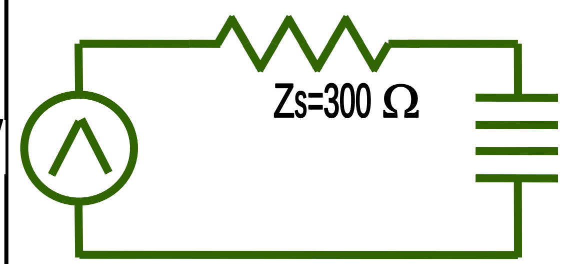


Voltages and Current for A Surge Arrester in a Simple Circuit

SIEMENS







- The peak current is 162.3 A.
- The voltage drop across the resistor is 0.1623 x 300 = 48.7 kV.
- The peak arrester voltage is 100 - 48.7 = 51.3 kV.

Surge Arrester Terms

SIEMENS

- Maximum Continuous Operating Voltage (MCOV)
- Voltage Rating (Duty Cycle Rating)
- Power-Frequency Sparkover Voltage
- Impulse Sparkover Voltage
- Discharge Current
- Discharge Voltage (Residual Voltage)
- Protective Level
- Protective Margin
- Arrester Class

Maximum Continuous Operating Voltage

SIEMENS

- MCOV
- Units are kV rms
- The maximum permissible steady state operating voltage
- MCOV $\geq$ Maximum System Operating Voltage
- Design value
- For example:
  - Nominal voltage is 13.8 kV rms line-line
  - Maximum line-neutral voltage is $1.05 \times 13.8/\sqrt{3} = 8.4$ kV rms
  - Select a catalog arrester with an MCOV $\geq$ 8.4 kV

Voltage Rating (Duty Cycle Rating)

SIEMENS

- kV rms
- The maximum permissible operating voltage between its terminals at which an arrester is designed to perform its duty cycle.
- Value on the nameplate

Power-Frequency Sparkover Voltage

SIEMENS

- kV rms
- The lowest power frequency sinusoidal voltage causing sparkover

Impulse Sparkover Voltage

SIEMENS

- kV peak
- The highest value of impulse voltage attained prior to the flow of discharge current.
- 1.2 x 50 μs standard wave shape

Discharge Current

SIEMENS

- A or kA peak
- The magnitude of the current that flows through an arrester following sparkover.

Discharge Voltage (Residual Voltage)

SIEMENS

- kV peak
- The voltage that appears across the terminals of an arrester during the passage of discharge current.
- Maximum values are usually available from the manufacturer for currents of 1.5, 3, 5, 10, 20, 40 kA with a wave shape of 8 x 20 μs
- 8 x 20 μs factory test wave shape rises to crest in 8 μs and decays to one-half crest value in 20 μs

Protective Level

SIEMENS

- Lightning Impulse Protective Level
- Switching Impulse Protective Level

Typical Arrester Characteristics

SIEMENS

Table 2a Polymer Station Arrester Characteristics									
				8/20 µs Maximum Discharge Voltage - kVcrest					
Rated Voltage kVrms	MCOV kVrms	0.5 µsec 10 kA Max IR-kVcrest	Switching Surge Maximum IR-kVcrest[1]	1.5 kA	3 kA	5 kA	10 kA	20 kA	40 kA
3	2.55	8.4	6.0	6.4	6.7	7.1	7.6	8.4	9.6
6	5.10	16.7	11.9	12.8	13.5	14.1	15.2	16.8	19.1
9	7.65	25.0	17.8	19.2	20.2	21.1	22.7	25.1	28.3
10	8.40	27.8	19.8	21.4	22.5	23.5	25.3	28.0	31.8
12	10.2	33.3	23.7	25.6	26.9	28.1	30.3	33.5	38.1
15	12.7	41.7	29.7	32.0	33.7	35.2	37.9	42.0	47.6
18	15.3	50.1	35.6	38.4	40.4	42.3	45.5	50.0	57.2
21	17.0	56.3	40.1	43.2	45.5	47.6	51.2	56.7	64.4
24	19.5	63.9	45.5	49.1	51.6	54.0	58.1	64.3	73.0
27	22.0	72.9	51.9	56.0	58.9	61.6	66.3	73.4	83.3
30	24.4	80.4	57.2	61.7	64.9	67.9	73.1	80.9	91.9
36	29.0	95.9	68.3	73.6	77.4	81.0	87.2	96.5	109.6
39	31.5	104.2	74.2	80.0	84.1	88.0	94.7	104.8	119.0
45	36.5	120.9	86.1	92.8	97.6	102.1	109.9	121.7	138.1
48	39.0	128.7	91.6	98.8	103.9	108.7	117.0	129.5	147.1
54	42.0	144.4	102.8	110.9	116.6	122.0	131.3	145.3	165.0
60	48.0	163.5	116.4	125.5	132.0	138.0	148.6	164.5	186.8
66	53.0	179.9	128.0	138.1	145.2	151.8	163.5	181.0	205.5
72	57.0	191.8	136.6	147.3	154.9	162.0	174.4	193.1	219.2
90	70.0	241.8	172.1	185.6	195.2	204.2	219.8	243.3	276.3
96	76.0	257.4	183.2	197.6	207.8	217.4	234.0	259.0	294.1
108	84.0	288.9	205.6	221.8	233.2	244.0	262.6	290.7	330.1
120	98.0	326.9	241.3	251.0	263.9	276.1	297.2	329.0	373.6
132	106.0	362.7	267.7	278.5	292.8	306.3	329.7	365.0	414.4
144	115.0	386.1	285.0	296.5	311.7	326.1	351.0	388.6	441.2

IEEE Defined Arrester Protective Margins

SIEMENS

- PM_{L1}=[(CWW/FOW)-1]*100 $\geq$ 20%

  CWW – Chopped Wave Withstand

  FOW – Front of Wave Protective Level

- PM_{L2}=[(BIL/LPL)-1]*100 $\geq$ 20%

  BIL – Basic Lightning Impulse Insulation Level

  LPL – Lightning Impulse Protective Level

- PM_{S}=[(BSL/SPL)-1]*100 $\geq$ 15%

  BSL – Basic Switching Impulse Insulation Level

  SPL – Switching Impulse Protective Level

SIEMENS

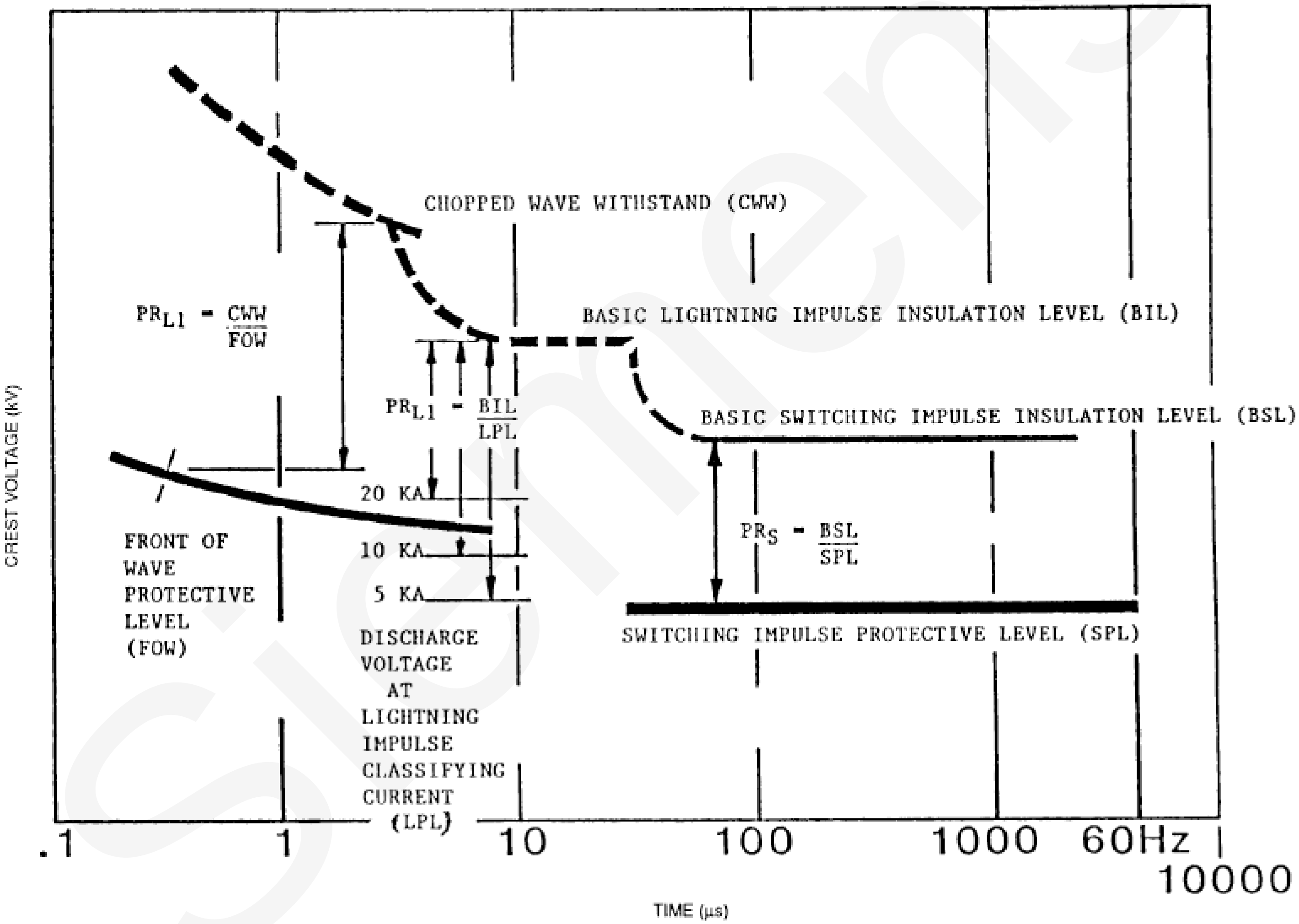


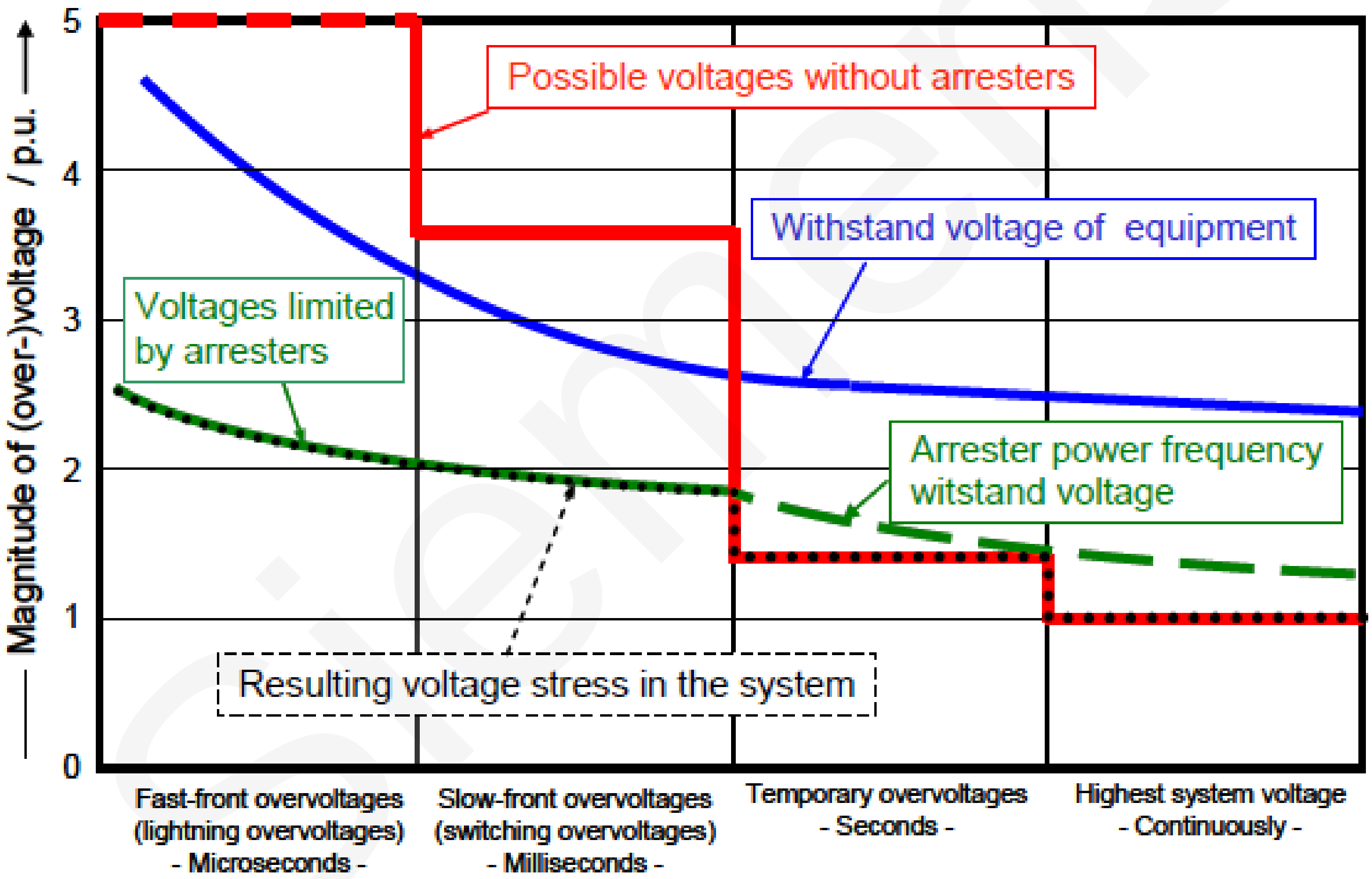
Fig 8
Typical Volt-Time Curve for Coordination of Arrester Protective Levels With Insulation Withstand Strength for Liquid-Filled Transformers

IEEE Std C62.22-1991

IEEE GUIDE FOR THE APPLICATION OF METAL-OXIDE

Insulation Coordination Concept

SIEMENS



Arrester Class

SIEMENS

- Station Class
- Intermediate Class
- Distribution Class
  - ANSI C62.1, Test Requirements for Arrester Classification.
  - ANSI C62.2, Arrester Characteristics

Station Class Arresters

SIEMENS

- Most rugged construction
- Greatest surge current discharge ability
- Lowest voltage drop
- Best equipment protection
- Recommended for
  - 150 kV and above substations
  - Large capacity substations
    - 10 MVA and above
  - Smaller but important substations

Surge Arrester Applications

- Overhead transmission & distribution lines
- Substation equipment
- Distribution equipment on overhead lines
- Underground distribution cables
- LV Secondary systems
- Generators & motors
- Commercial/Industrial loads

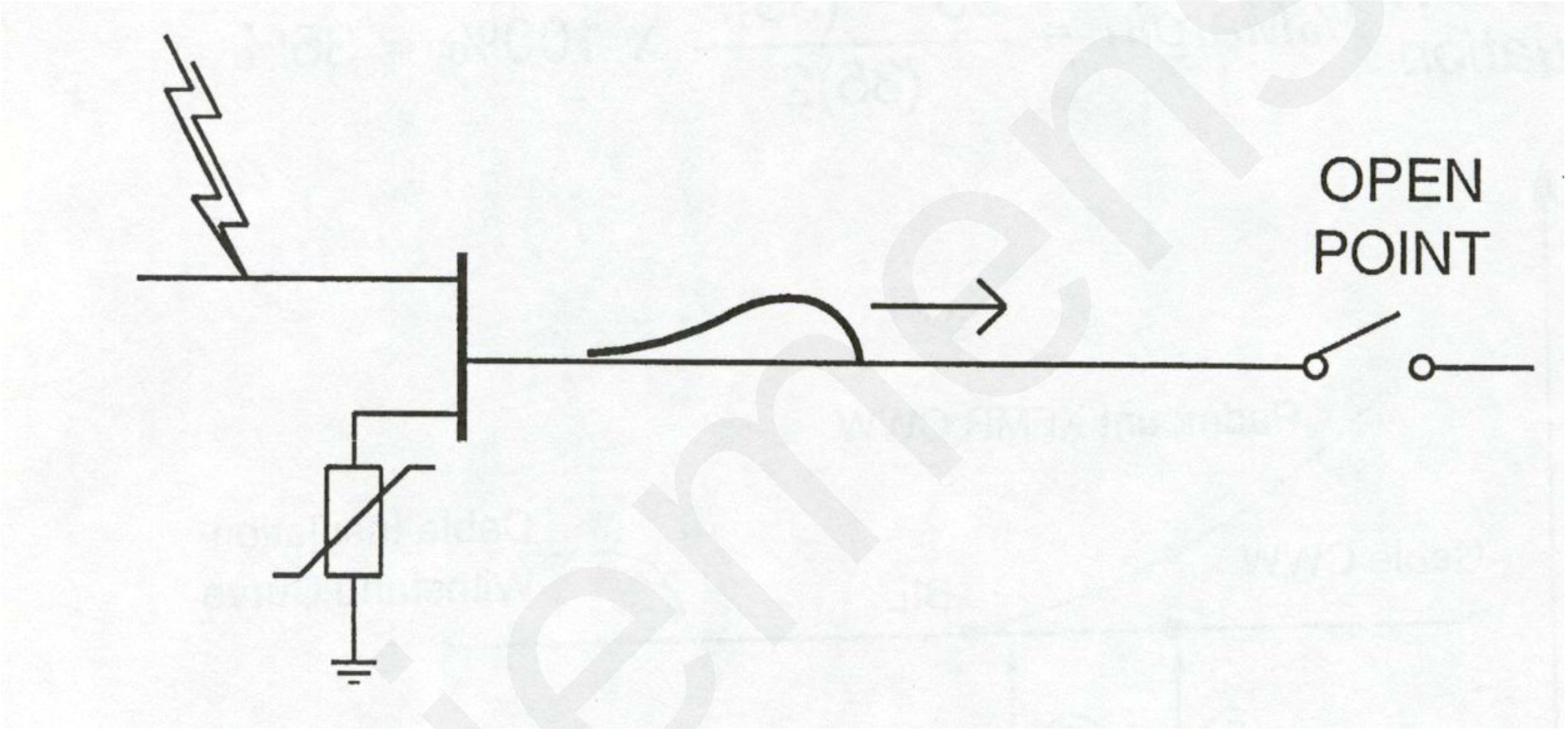
Surge Arrester Locations in Open Air Systems

SIEMENS

- Power & distribution transformers
- Shunt and series reactors
- Shunt and series capacitor banks
- Cable terminations
- GIS terminations
- Switching equipment
- OH Line terminations in substations (optional)
- OH Line towers & poles (optional)

Cable with Riserpole Arrester Only

SIEMENS

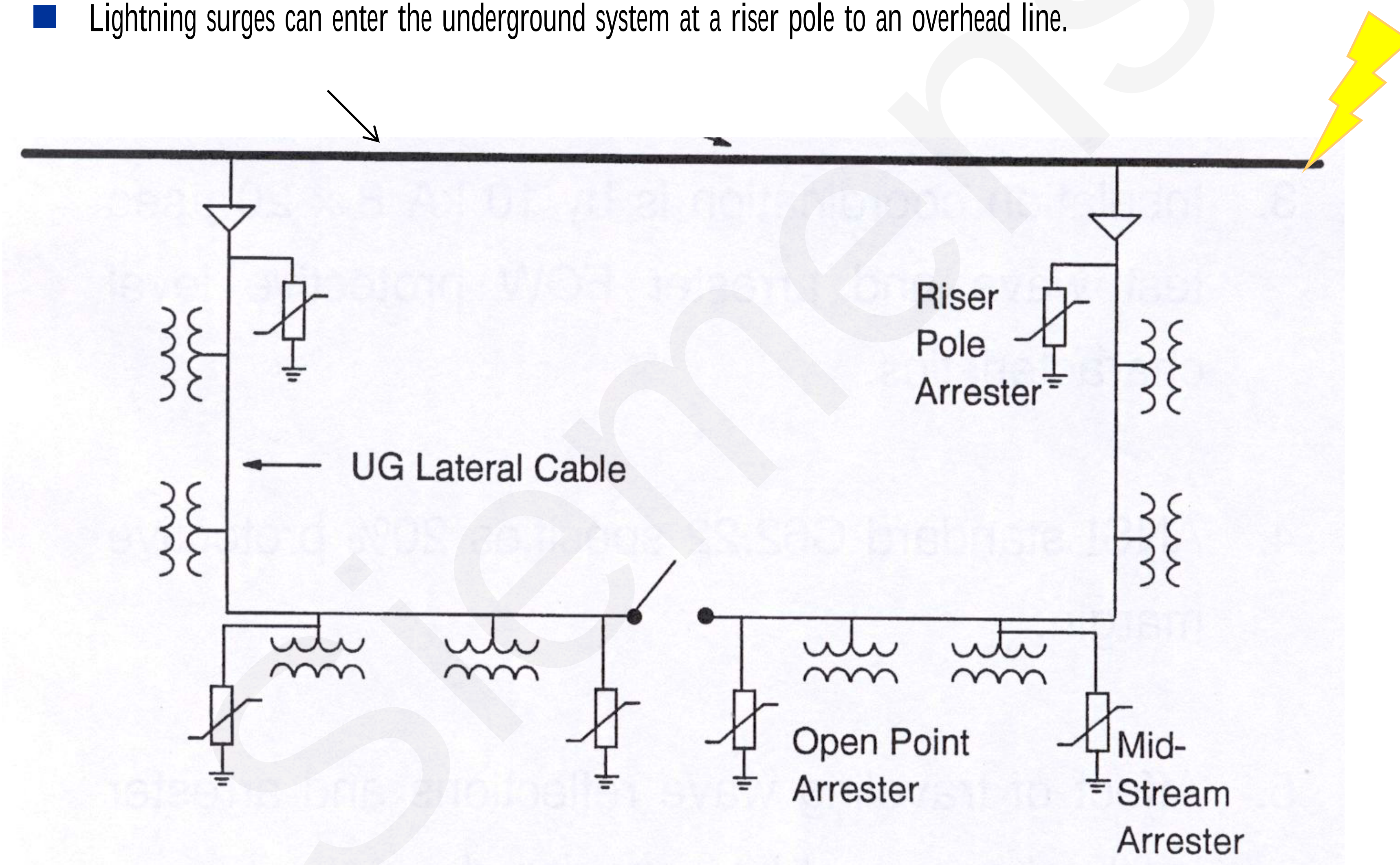


115 kV OH to Cable at Lake Champlain

SIEMENS

Surge Arrester Locations in UG Cable Systems

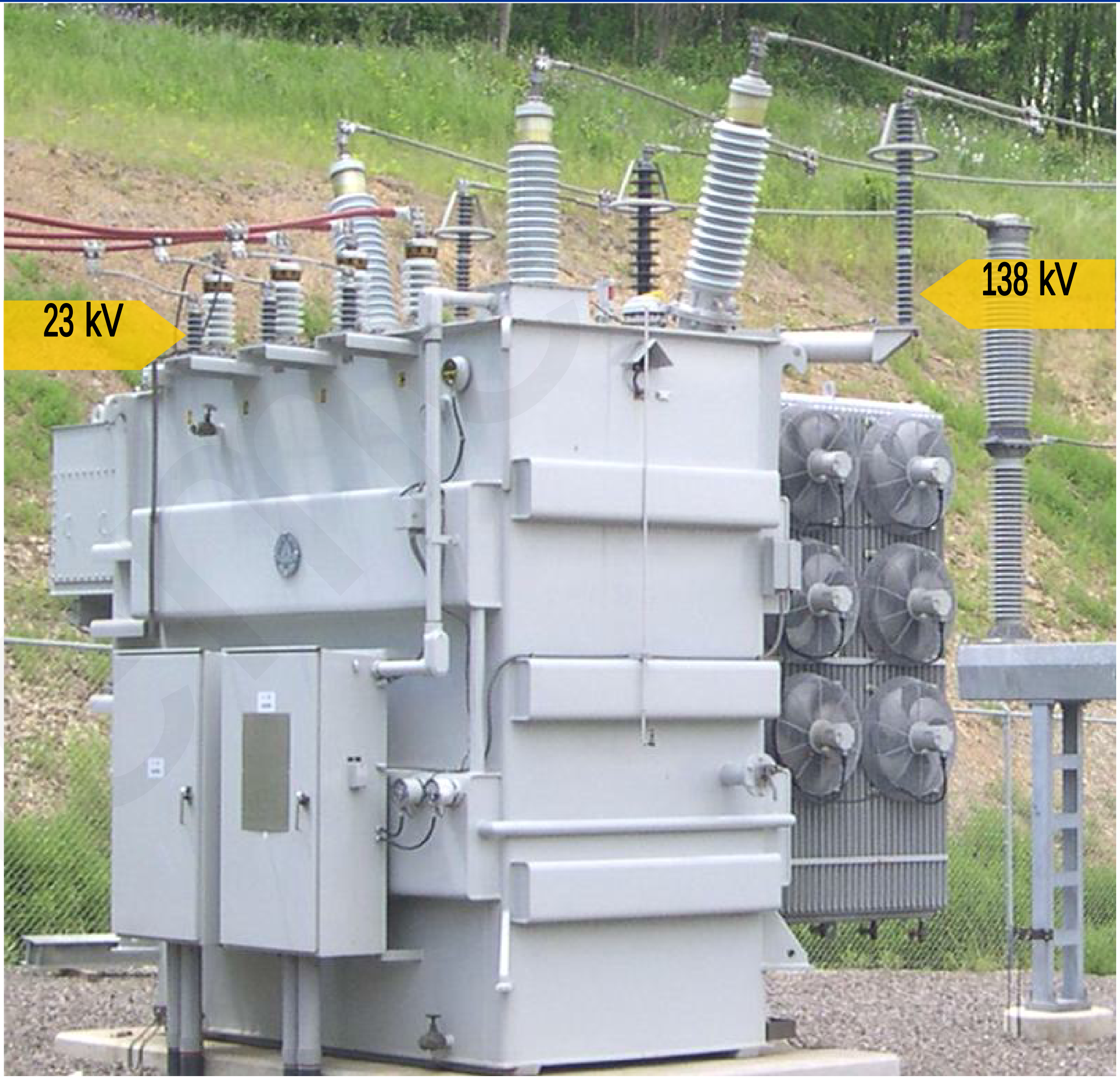
- Lightning surges can enter the underground system at a riser pole to an overhead line.



Distribution Substation Power Transformer

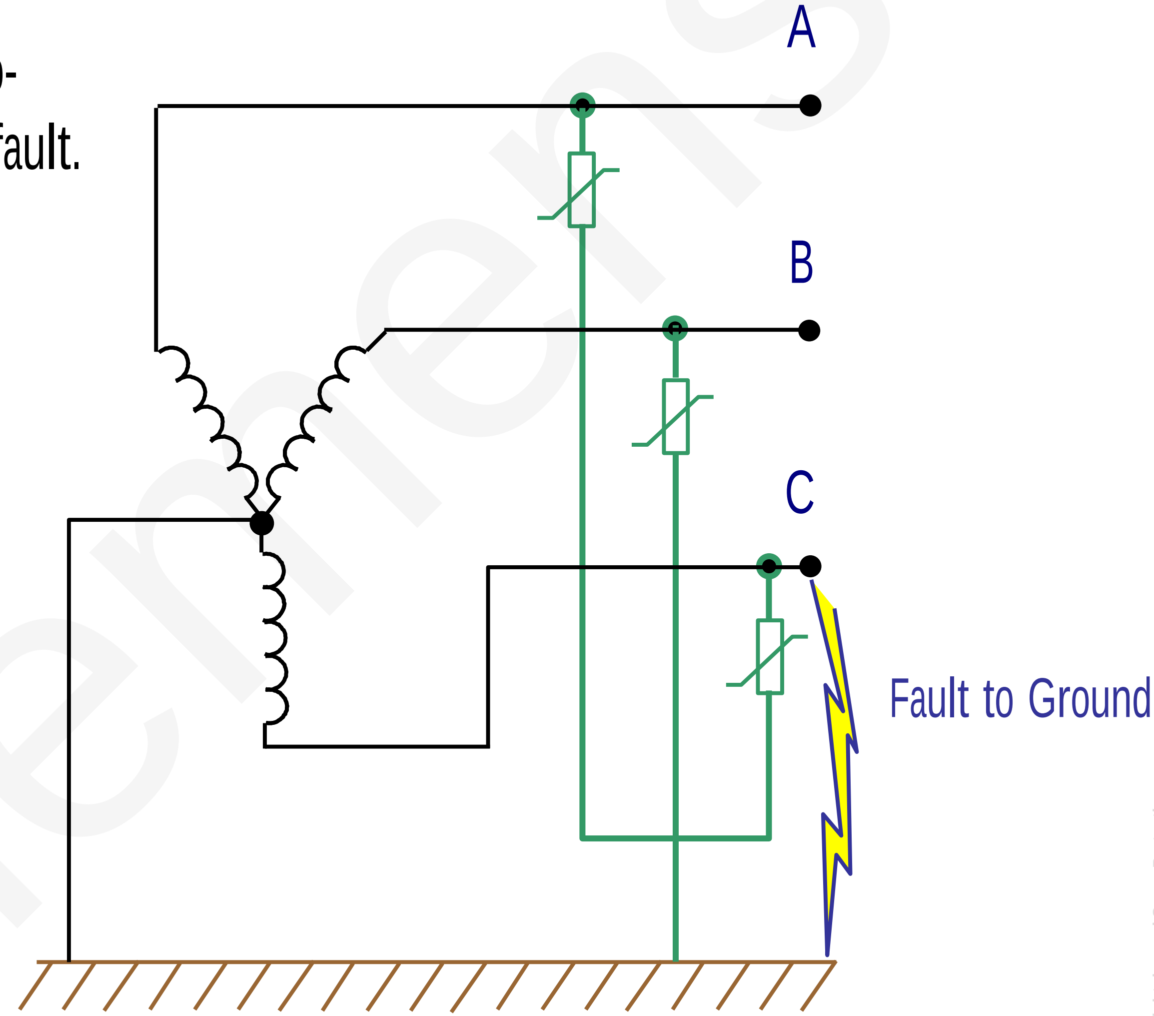
SIEMENS

- mount on tank
- close to bushings
- HV & LV sides



Solidly Grounded System

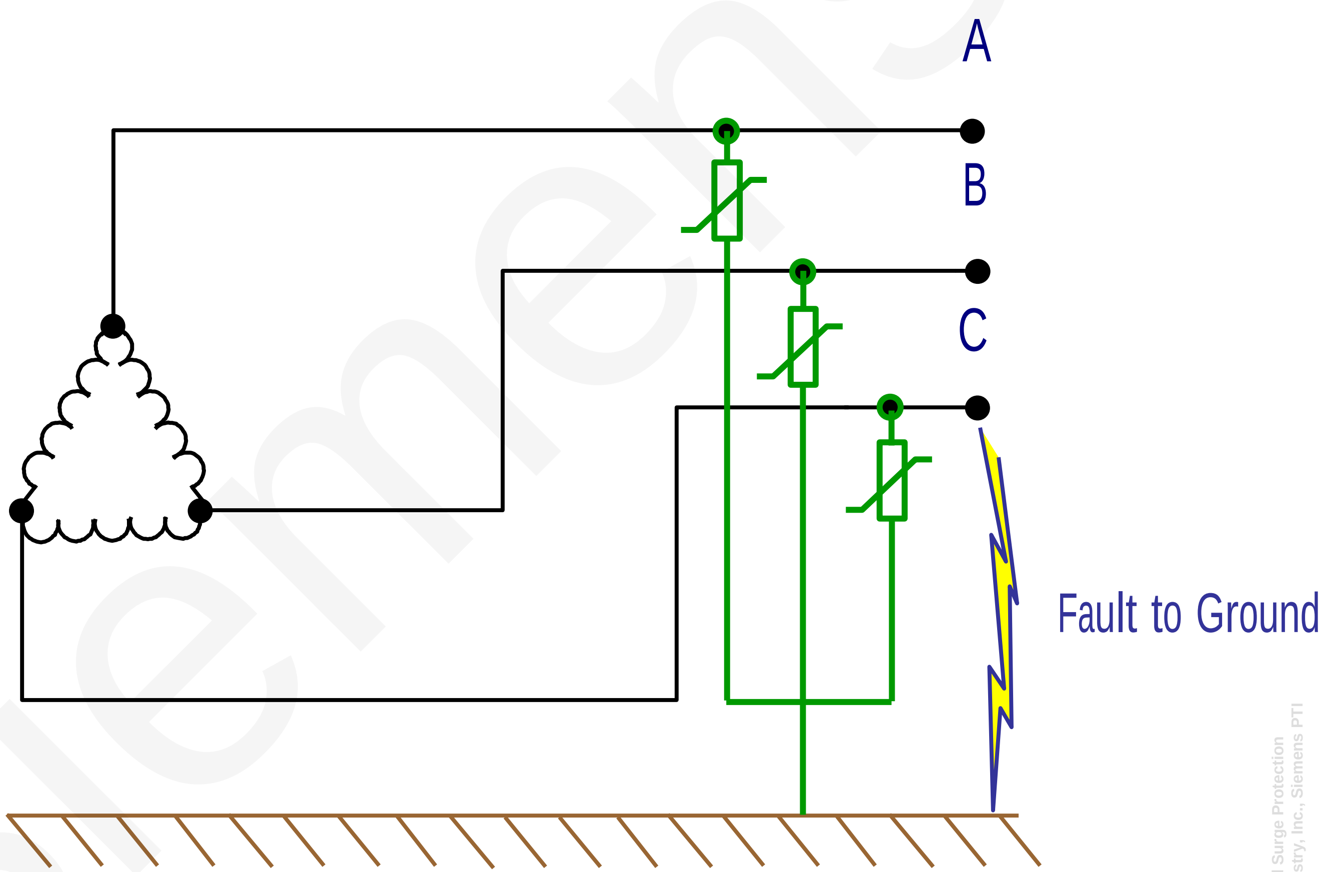
- Arrester subjected to line-to-ground voltage during the fault.
- MCOV $\geq V_{LN}$



Ungrounded System

SIEMENS

- Arrester subjected to line-to-line voltage during the fault.
- MCOV ≥ V_{LL}



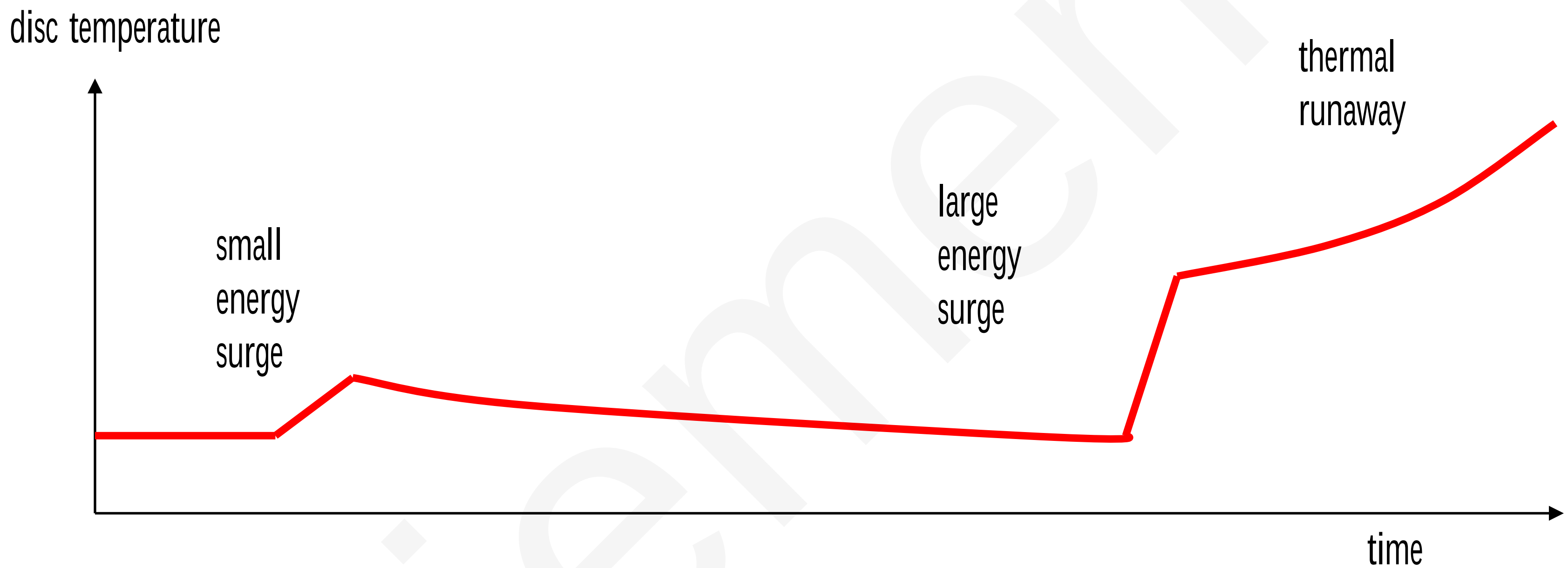
60 Hz Voltage Consideration in Applying MOV Arresters

SIEMENS

- Make sure arrester MCOV is at least as high as the maximum sustained voltage on the system.
- For ungrounded systems, the maximum sustained voltage can be the phase-to-phase voltage.
- For multi-grounded systems, make sure arrester TOV capability is not exceeded during faults.

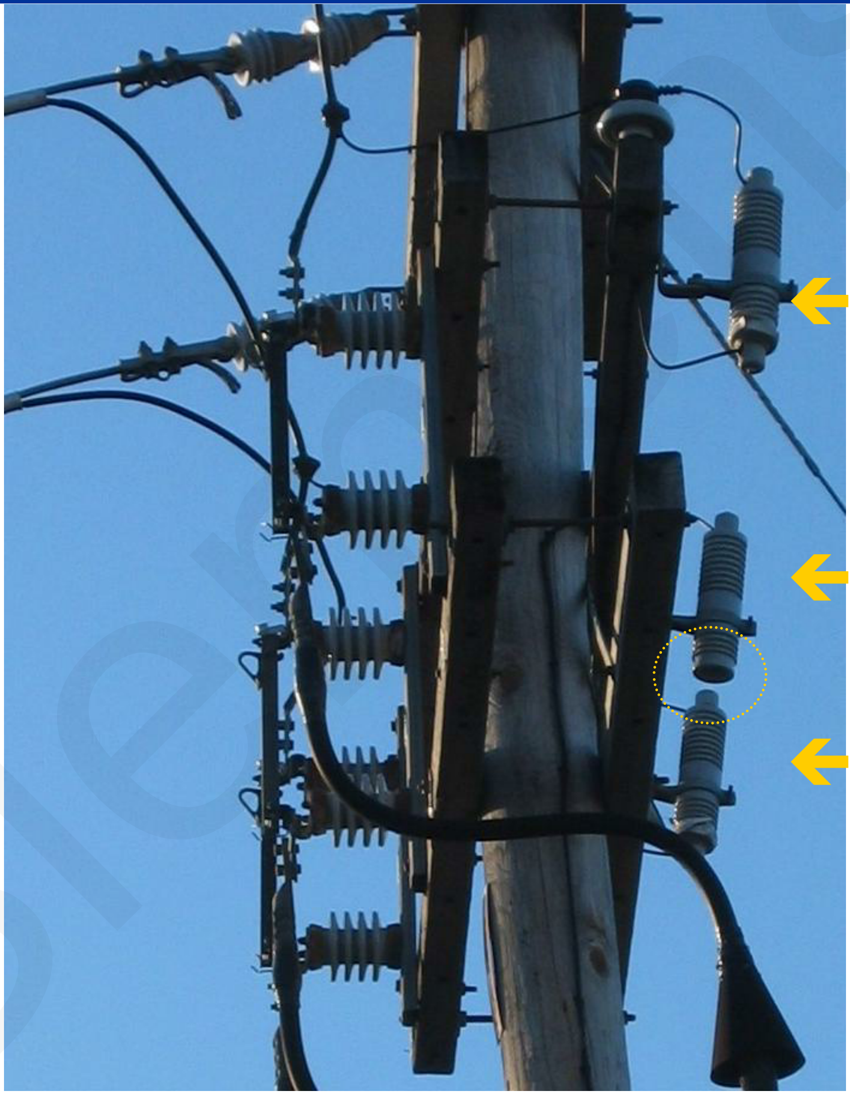
Thermal Runaway

SIEMENS



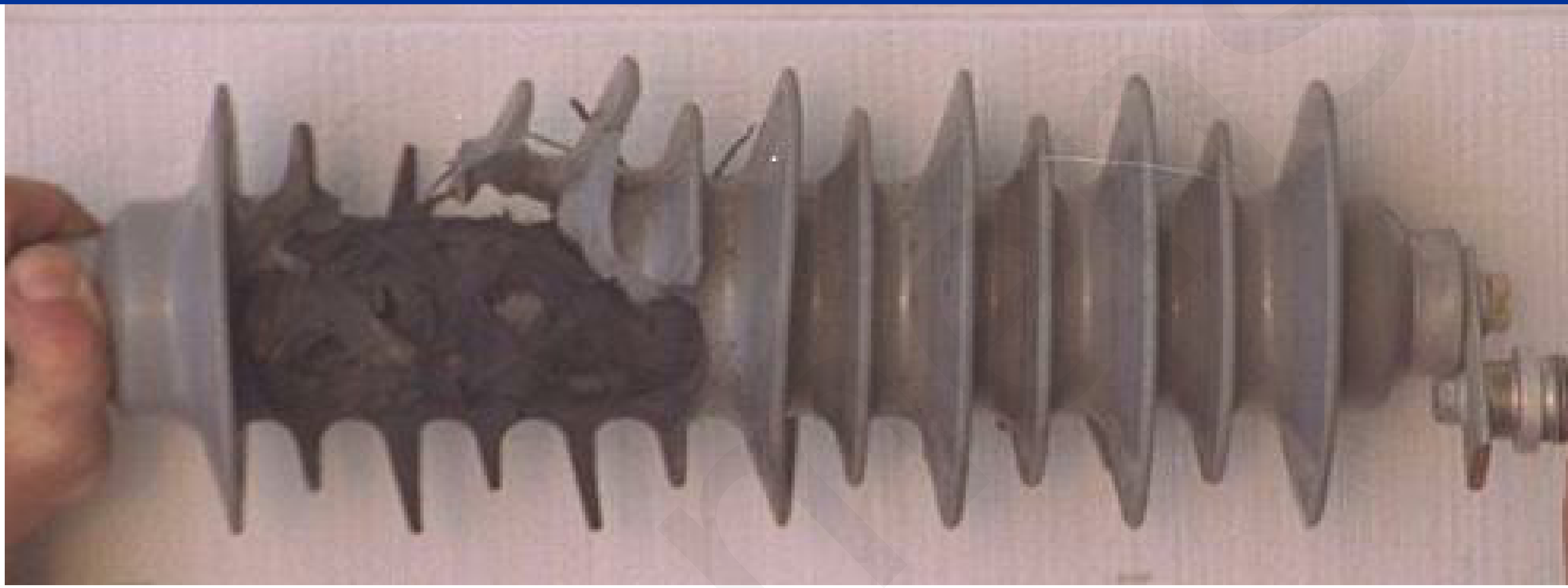
Failed Arrester - Porcelain Construction

SIEMENS



Silicone MOV Arrester Damage Following Test

SIEMENS



Summary

SIEMENS

- Arresters must present a high impedance for steady state voltages and modest levels of TOV.
- Arresters must discharge significant current and absorb energy during lightning and switching surges.
- Arresters protect insulation by limiting the surge voltage below the insulation failure level.
- Metal oxide varistors (MOV) and silicon carbide (SiC) gapped arresters have been installed.
- MOVs are used for new applications or replacements.

IEEE Std C62.22

- IEEE Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems